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Attachment 2
Turcic Declaration with Exhibits

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

STEPHEN F. GASS

Serial No.: 10/100,211 Examiner Boyer D. Ashley

Filed: March 13, 2002 Group Art Unit 3724

For: SAFETY SYSTEMS FOR POWER EQUIPMENT

To: Commissioner for Patents
Attention: Examiner Boyer D. Ashley
Group Art Unit 3724
P.O. Box 1450
Alexandria, Virginia 22313-1450

DECLARATION OF DR. DAVID A. TURCIC

I, David A. Turcic, declare as follows:

1. I am an Associate Professor of Mechanical Engineering at Portland State University in Portland, Oregon. I have worked as an Associate Professor at Portland State University since 1992 and I received tenure in 1994. I have also taught mechanical engineering at Pennsylvania State University, Drexel University, and the University of Wisconsin, Madison where I was also a tenured associate professor.

2. I earned a Ph.D. degree in mechanical engineering from Pennsylvania State University in 1982. I had previously earned masters and bachelor degrees in mechanical engineering from Pennsylvania State University.

3. A copy of my resume is attached as exhibit 1.

4. I have also been a woodworker for many years and I am familiar with the construction and operation of band saws and table saws. I personally own a table saw and a band saw.

5. I understand that the above-identified patent application titled "Safety Systems for Power Equipment" is currently pending before the U.S. Patent and Trademark Office. I also understand that the application includes claims 1 and 22-24 that describe various machines with a mechanical cutting tool and a safety system adapted to detect an unsafe condition between a person and the cutting tool. The safety system includes a detection subsystem to detect the unsafe condition and a reaction subsystem to mitigate the unsafe condition. The reaction subsystem includes "a brake mechanism adapted to stop at least one motion of the cutting tool within 10 milliseconds after detection of the unsafe condition."

6. I am aware that claims 1 and 22-24 from the above-identified application have been rejected as anticipated by U.S. Patent No. 3,858,095 to Friemann et al. I have read and studied a communication from the Patent Office mailed February 8, 2005 setting forth the bases for that rejection. In support of that rejection, the Patent Office said the Friemann patent discloses a band cutter machine with a band cutter and a brake system that can stop the movement of the band cutter within 10 milliseconds after detecting contact between a person and the cutter. I am also aware that the Friemann patent itself says it is possible to stop the band cutter within 5 or 10 milliseconds using the circuits and brake systems disclosed in the patent.

7. I have been retained to offer an independent expert opinion as to whether the Friemann patent discloses a brake system capable of stopping the movement of the band cutter within 10 milliseconds after detecting contact between a person and the cutter, and whether the Friemann patent discloses such a brake system sufficiently for an ordinary mechanical engineer to make one.

8. I have read and studied the Friemann patent and I understand its disclosure. In my opinion, the brake systems disclosed in the Friemann patent cannot stop the band cutter within 10 milliseconds after detecting contact between a person and the cutter and Friemann fails to teach or suggest any way to make such a brake system. Based on the disclosure in the Friemann patent combined with my knowledge of mechanical engineering, I personally do not know of any way to make a brake system as disclosed in the Friemann patent capable of stopping the motion of the band cutter within 10 milliseconds after detecting contact between a person and the cutter. My opinions are explained in the following paragraphs.

9. Friemann discloses a protective circuit for a band cutter used in the textile industry. (Friemann, column 1, lines 5-11.) The machine includes a band cutter looped around three rollers and one pulley. (Friemann, Fig. 2.) A motor drives the pulley to move the cutter and a user slides a piece of textile past the moving cutter to cut the textile. The protective circuit is designed to stop the cutter in the event a person touches the moving cutter. (Friemann, column 1, lines 45-47.) The protective circuit stops the cutter by triggering direct current

braking of the motor and by triggering an electromechanical brake to decelerate the drive pulley or flywheel of the motor. (Friemann, column 3, lines 66-68 & column 4, lines 3-5.) Stopping the motor and pulleys causes the band cutter to stop. More specifically, the circuit includes an oscillator with a voltage output connected to a bridge circuit. The bridge circuit is balanced until an operator touches the band cutter at which time the bridge circuit becomes unbalanced and a voltage is transmitted to an amplifier circuit which, in turn, trips relays to supply power to the DC braking and electromechanical brake. (Friemann, column 3, line 35 to column 4, line 6.)

10. The relays disclosed in the Friemann patent that switch power to the motor and electromechanical brake are shown as standard relays. Such relays conservatively take 5 to 15 milliseconds or more to operate. Attached as exhibit 2 are specifications for standard motor control relays showing coil operating times of 10 to 25 milliseconds.

11. Friemann discloses two embodiments of circuits to control the motor and electromechanical brake. In the first embodiment Friemann states that relay R1 is energized when a person contacts the cutter. (Friemann, column 3, lines 53-55.) Relay R1 then closes contact pair $R1_1$ - $R1_2$ and that contact pair energizes relay *h*2 to close contact $h2_1$. Closing contact $h2_1$ then energizes relay *c*2 and energizing relay *c*2 connects direct current to the motor and alternating current to the electromechanical brake. It is only after relays R1, *h*2 and *c*2 are sequentially energized that braking can begin. (Friemann, column 3, line 53 to column 4, line 3.) That means the DC braking of the motor and the

electromechanical brake cannot even begin to operate in this embodiment until 15 to 45 milliseconds after the system detects contact because each relay takes 5 to 15 milliseconds to energize. In the second embodiment, relay R1 is energized when a person contacts the cutter. (Friemann, column 4, lines 38-40.) Relay R1 then closes contactor pairs $R1_1$ - $R1_2$ and $R1_5$ - $R1_6$ and opens contactor pair $R1_3$ - $R1_4$. Those contactors, in turn, actuate an electronic reversing switch and energize a second relay *c*2. The electronic reversing switch switches power to the motor and relay *c*2 switches power to the electromechanical brake. (Friemann, column 4, lines 40-53.) In this embodiment, the DC braking of the motor cannot begin to operate until after relay R1 and the electronic reversing switch are sequentially energized, and the electromechanical brake cannot begin to operate until after relays R1 and *c*2 are sequentially energized.

12. Because Friemann's braking system uses standard relays, Friemann's motor braking and electromechanical brake will not even begin to operate within 10 milliseconds after detection of contact between a person and the band cutter. I am aware that Dr. Stephen F. Gass has submitted a declaration signed April 26, 2004 in connection with this application, and he discussed this point in his declaration. I have read, studied and understand Dr. Gass' declaration and I agree with Dr. Gass' discussion of this point.

13. After the relays have energized, the motor brake and the electromechanical brake disclosed in Friemann operate to decelerate the band cutter. However, even if the relays could switch power to the motor and brake

instantaneously, which they cannot, the motor and brake still could not stop the band cutter within 10 milliseconds because motors take time to stop and brakes take time to engage.

14. The motor used in Friemann's machine is an AC induction motor. This is evident from the disclosure in the patent showing that the motor is connected to 3-phase power and from the disclosure showing how to connect direct voltage to two phases of the motor to cause DC braking. (Friemann, Fig. 4, column 3, lines 34-41 and 65-67.) I do not know of any AC induction motor capable of stopping Friemann's band cutter within 10 milliseconds by application of DC braking. The rotational inertia of the motor armature prevents that result.

15. The rotational inertia of the armature in Friemann's motor will depend on the speed at which the armature is spinning. That speed can be calculated from Friemann's statement that the usual speed of a band cutter is 14 meters per second (Friemann, column 2, lines 18-19) and from the size of the rollers and pulley used in Friemann's system. Figure 2 in Friemann shows the size of the rollers and pulley in relation to the band cutter machine. The machine is positioned on the floor with a table at a standard height above the floor. The radius of each roller and pulley is about 1/5 of the distance from the floor to the table. Tables are typically 34-36 inches above the floor, so the radius of each roller and pulley would be around 6.8 to 7.2 inches or 17.3 to 18.3 cm. That is consistent with my personal knowledge of band cutters. In order to drive the band cutter at 14 meters per second around pulleys with radii of 17 cm, each pulley would have an angular velocity of 82.35 radians per second. Figure 2 in

Friemann also shows a motor pulley that is approximately one half the size of drive pulley 9. Therefore, the motor would have to operate at twice the speed of the drive pulley. I calculated the pulley speed to be 82.35 rad/sec, as set forth above, so the motor speed would then be 164.7 rad/sec or 1572.8 rpm. A motor speed close to that speed and commonly available in different motor sizes is 1760 revolutions per minute.

16. Friemann does not specify any particular size of motor to use in his machine, but band cutters often use 3 horsepower motors. A general purpose, 3 hp, 60 Hz, AC induction motor from Baldor Electric Company (Catalog Number VEM3661T) running at 1760 rpm (184.31 radians per second) has a maximum or break down torque of 31 lb-ft or 42 N-m and a rotational inertia of approximately 0.26 lb-ft^2 or 0.01095 kg-m^2. (The break-down torque of this motor and the break-down torques of other motors discussed herein are taken from performance data set forth by Baldor at www.baldor.com, copies of which are attached as exhibit 3. The rotational inertias of the armatures in the motors discussed herein were obtained during telephone calls with Baldor.) With a torque of 42 N-m, assuming it could be applied instantaneously and continuously over the entire deceleration of the motor armature, which it cannot, the time required to stop the motor armature alone, disregarding the pulleys, would be 48 milliseconds, as shown by the following calculation, where "t" is the time, "ω_0" is the initial angular velocity of 184.31 radians per second, "ω" is the final angular velocity of zero, "I" is the rotational inertia, and "τ" is the torque:

$$t = (\omega_0 - \omega)\, I / \tau$$

$$t = (184.31 \text{ rad/sec} - 0)\,(0.01095 \text{ kg-m}^2) / 42 \text{ N-m}$$

$$t = 0.048 \text{ sec or } 48 \text{ milliseconds.}$$

17. A general purpose, 15 hp, 60 Hz, AC induction motor from Baldor (Catalog Number M2333T) running at 1760 rpm (184.31 radians per second) has a maximum or break down torque of 147 lb-ft or 199.3 N-m and an inertia of approximately 1.38 lb-ft^2 or 0.05811 kg-m^2. With that torque, again assuming the torque could be applied instantaneously and continuously, the time required to stop the armature alone would be:

$$t = (\omega_0 - \omega)\, I / \tau$$

$$t = (184.31 \text{ rad/sec} - 0)\,(0.05811 \text{ kg-m}^2) / 199.3 \text{ N-m}$$

$$t = 0.0537 \text{ sec or } 53.7 \text{ milliseconds.}$$

18. A general purpose, 50 hp, 60 Hz, AC induction motor from Baldor (Catalog Number CM4115T) running at 1770 rpm (185.35 radians per second) has a maximum or break down torque of 399 lb-ft or 540.1 N-m and a rotational inertia of 6.37 lb-ft^2 or 0.2682 kg-m^2. With that torque, again assuming the torque could be applied instantaneously and continuously, the time required to stop the armature alone would be:

$$t = (\omega_0 - \omega)\, I / \tau$$

$$t = (185.35 \text{ rad/sec} - 0)\,(0.2682 \text{ kg-m}^2) / 540.1 \text{ N-m}$$

$$t = 0.092 \text{ sec or } 92 \text{ milliseconds.}$$

19. As can be seen from the analysis of the three typical AC motors presented above, these motors cannot stop themselves in 10 milliseconds.

Therefore it is not possible for these motors to stop themselves plus the rollers and pulley that drive Friemann's band cutter in 10 milliseconds.

20. I am aware of a high performance brushless, 9.1 hp, DC motor capable of stopping its own armature from an operating speed of 1760 rpm in approximately 6 milliseconds (Model BM4500E from Aerotech, Inc. of Pittsburgh, Pennsylvania, having a rotational inertia of 0.00308 kg-m^2). However, that motor has a peak torque of only 94.4 N-m and therefore is too small to stop itself and the band cutter disclosed in Friemann within 10 milliseconds. Using a conservative estimate of 0.092 kg-m^2 for the rotational inertia of the three rollers and one pulley included in Friemann's machine (this inertia is calculated below in paragraph 23), this high performance DC motor would take approximately 86.6 milliseconds to stop itself and the rollers and pulley. This motor and the associated amplifier cost approximately $5700. I am not aware of any larger, more powerful brushless DC motors capable of stopping themselves and Friemann's rollers and pulley within 10 milliseconds. Additionally, the circuitry disclosed in Friemann to control the motor braking would not work with a DC motor.

21. Friemann also discloses using an electromechanical brake. Electromechanical brakes apply electromagnetic force to move an armature into contact with a braking surface. The armature typically is connected to the shaft to be braked and spins with the shaft. When the electromagnetic force moves the armature into contact with the braking surface, friction between the armature and braking surface decelerates both the armature and the shaft. The

electromagnetic force is generated by a wire coil and the size of the coil determines the amount of force that can be applied. However, it takes time to charge the coil to create the electromagnetic force because of the inductance of the coil and it also takes time to move the spinning armature into contact with the braking surface because of the mass and inertia of the armature. As far as I am aware, electromechanical brakes capable of applying a 200 N-m braking torque typically take about a quarter of a second or more to engage. For example, Model EMB-S200A is a standard DC electromechanical brake manufactured by Electric Motor & Transmission Pty. Ltd. that is capable of applying 200 N-m of torque. The time for that brake to engage is 300 milliseconds. A specification sheet showing the operating time for this brake and other brakes is attached as exhibit 4. Larger brakes capable of applying greater stopping torques take even more time to engage because the larger brakes have coils with higher inductance and armatures with more mass. I do not know of any electromechanical brake that can work with a motor brake to stop a band cutter as disclosed in Friemann within 10 milliseconds, and in my opinion, no such electromechanical brake exists.

22. Figure 2 in Friemann shows that the band cutter runs over three guide rollers and one drive pulley. All of those rollers and pulley must stop in order to stop the band cutter. Adding the rotational inertia of the rollers and pulley to the rotational inertia of the motor armature further lengthens the time required for the motor and electromechanical brake to stop the band cutter.

23. The radius of each roller and pulley used in Friemann's system is around 6.8 to 7.2 inches or 17.3 to 18.3 cm, as explained above. The mass of the perimeter of each roller and pulley is conservatively no less than 0.8 kg. Based on this information, and considering the mass to be at the perimeter, the rotational inertia of a single roller or pulley can be calculated as follows:

$$I = m\, r^2$$

$$I = (0.8\text{ kg})\,(0.17\text{m})^2$$

$$I = 0.023\text{ kg-m}^2$$

The rotational inertia of three rollers and one pulley would then be 0.092 kg-m^2.

24. Each roller and pulley will have an angular velocity of 82.35 radians per second, as explained above. The torque required to stop the rollers and pulley spinning at that speed within 10 milliseconds can be calculated as follows:

$$\tau = (\omega_0 - \omega)\, I / t$$

$$\tau = (82.35\text{ rad/sec} - 0)\,(0.092\text{ kg-m}^2)\,/\,0.01\text{ sec}$$

$$\tau = 757.62\text{ N-m.}$$

Friemann's DC motor braking and electromechanical brake must supply this torque instantaneously and continuously after someone touches the band cutter in order to stop the band cutter within 10 milliseconds. That, however, is impossible because motors and brakes big enough to generate that torque cannot operate in that time frame, as explained.

25. I am aware that Dr. Gass set forth in his declaration a calculation of the energy of the rollers and pulley when spinning and that he assumed each roller and pulley to have a radius of 20 cm and a mass of 2 kg at the perimeter. I agree with Dr. Gass' calculations for rollers and pulleys of that radius and mass. The radius and mass of rollers and pulleys used by Dr. Gass in his calculations are typical for band cutting machines while the radius and mass used in my calculations are more conservative.

26. The facts expressed herein conclusively establish that the mechanism disclosed in the Friemann patent cannot stop the band cutter within 10 milliseconds after a person touches the band cutter and the statements in the Friemann patent to the contrary are incorrect. I do not know of any way that the mechanism disclosed in the Friemann patent could stop the band cutter within 10 milliseconds after the device detects a person touching the band cutter, and the disclosure in Friemann is insufficient to instruct a mechanical engineer with an ordinary level of skill how to make such a brake mechanism. I do not know of any AC or DC motor or any electromechanical brake that can together stop the band cutter disclosed in Friemann within 10 milliseconds after a person touches the blade and I do not believe they exist.

27. I hereby declare that all statements made herein of my own knowledge are true and all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Date: 5-25-05

Dr. David A. Turcic